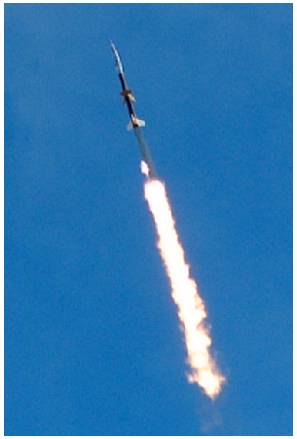
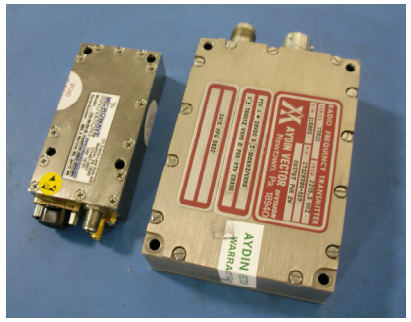
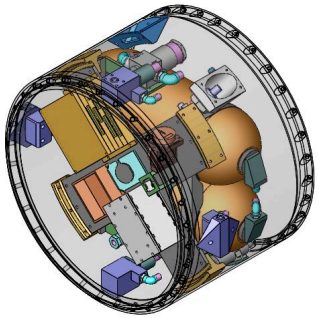




Sounding Rocket Working Group
June 21, 2007

NASA Sounding Rocket Operations Contract
(NSROC)



Goddard Space Flight Center

SRWG Agenda - NSROC

NSROC State of Affairs	Rob Maddox
Electrical Engineering	Shelby Elborn
Mechanical/Vehicle Engineering	Giovanni Rosanova
Guidance, Navigation & Control	Ron Kiefer
Conclusions	Rob Maddox

Program Manager

Rob Maddox

NSROC Programmatic

- Contract Status
  - Approaching mid point of Contract Year 9
  - Maintaining very good PEB scores
  - Open recruits on hold
  - Will reduce staff by 9 FTEs by end of year thru attrition
    - Staff replacement will be made as budget allows or critical demand
    - Organizational adjustments may be necessary

- Sub Contract Status
  - Bristol
    - Current order of 12 BB motors almost complete
    - New procurement initiated for 18 BB motors. Begin delivery this Fall
  - Aerojet – Maintained minimal support for Mk VI systems
  - U. of Wisconsin – Ongoing support for ST5000
  - PSL – Ongoing support for instrumentation systems
  - Herley Industries – Significant order placed for radar transponders

NSROC Programmatic

- Challenges
  - Implement new technology
    - Attitude Control Systems
    - Vehicle configurations
    - Electrical Systems
  - Complex Missions
    - Methods outside experience envelope
  - Budget
    - Balancing staff, procurements, reimbursable workload

NSROC Programmatic

- ITAR
  - NGTS export compliance office questioned employee travel to Norway for launcher installation
  - Sector review determined we needed ITAR exemption or TAA to proceed with launcher installation and follow on mission support.
  - ITAR exemption could not be granted by NASA so we initiated TAA process
  - NG TAA was delivered to Dept. of State on 6/15
  - NG and NASA export will push priority thru Dept. of State
  - NSROC subcontractors need to follow same process
  - CS team with NG technical lead currently in Norway installing launcher
  - First project team plans to travel mid July if TAA gets approved

NSROC Programmatic

- Safety Close Calls
  - All corrective actions from last year's close calls have been implemented
  - No safety close calls have occurred since last SRWG
  - Operational Safety Supervisor (OSS) role being enhanced
  - OSS will be from independent work group - NSROC SQA & Code 803
  - OSS will perform more QA functions in addition to safety oversight
  - Dashboard metrics implemented to track safety related leading indicators.

- Additional training for employees
  - Hazardous procedure upgrades
  - Proper procedure protocol
  - Task closeout documentation and photos

NSROC Programmatic

- Recent Reimbursable Projects (since last SRWG)
  - US Navy Aegis FTM-11.4: One Terrier Orion mission
  - US Navy Aegis FTM-12: Two Terrier Orion missions
  - LIDS Manufacturing Task
  - HyBolt TM and T&E Services
  - RPCS+ for WMSR
  - USAF Airborne Laser MARTI: Manufacturing and design support

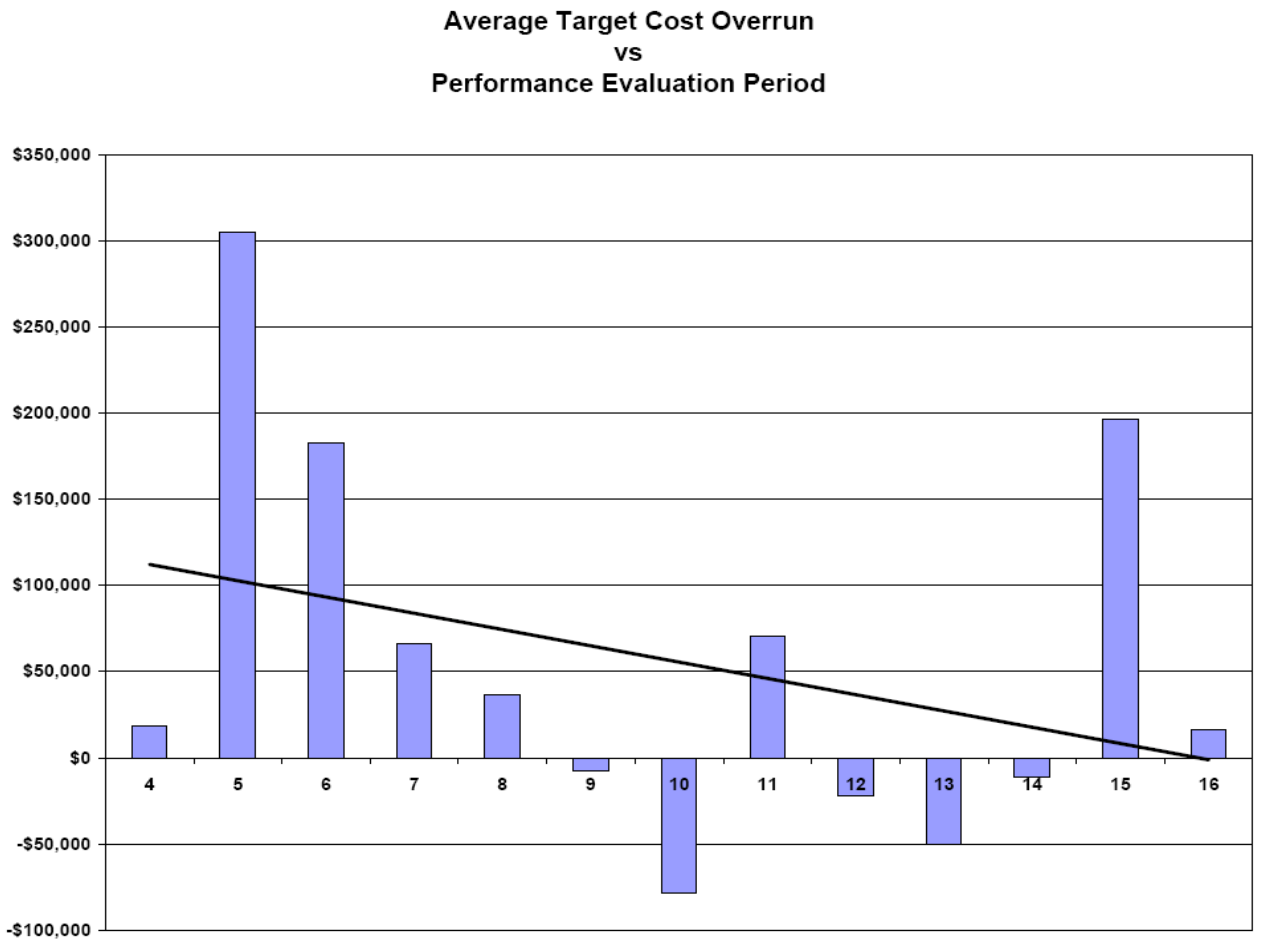
NSROC Programmatic

- New Business Opportunities (since last SRWG)
  - US Navy Aegis FTM-13: Two Terrier Orion missions
  - US Navy JFTM-1: One Terrier Oriole mission
  - USAF Airborne Laser MARTI 1&2: Two BBIX missions
  - USAF Airborne Laser: Five Terrier Lynx missions
  - MDA LeClair: One Black Brant XI mission
  - US Navy TSER Program – NGTS Proposal Pending
  - MDA DET LCAT Program – Decision to No Bid
  - US Navy SCSC Fleet Training Rockets – Early Discussions
  - Langley – HyBolt support underway

NSROC Programmatic

- Student Outreach/Intern & Co-op Programs
  - 2006 students (Spring 4; Summer 6; Fall 3)
  - 2007 (Spring 5; Summer 9; Fall 4)
  - 69 students have participated in this program; NSROC has hired 7 Intern/Coop graduates as full time engineers; another works for NG Space Systems in CA; 2 have achieved Doctorates; 9 have achieved Masters Degrees; 8 others are currently pursuing Masters Degrees.
  - ESCC Intern Program: 6 ESCC student have been hired as interns; 3 have been hired as FTE Techs. 3 of the FTE's are pursuing BSE degrees.
  - NSROC Extern Program began 1/8/07 with 2 VT students; both wanted to pursue internships.

SRWG Findings #2 Discussion



Electrical Engineering

Shelby Elborn

Wide Band, High Efficiency S-Band Transmitters

Issues

- PCM downlink operating over 1.5M Bit/Sec requires 10 Watt Wide Band transmitter
- The 10 Watt transmitter requires 3.1 Amps to operate and produces ~ 75 Watts of heat
- Existing 2, 5 & 8 watt narrowband transmitters are not frequency agile

Solutions

- Procure new higher bandwidth, higher efficiency frequency agile units

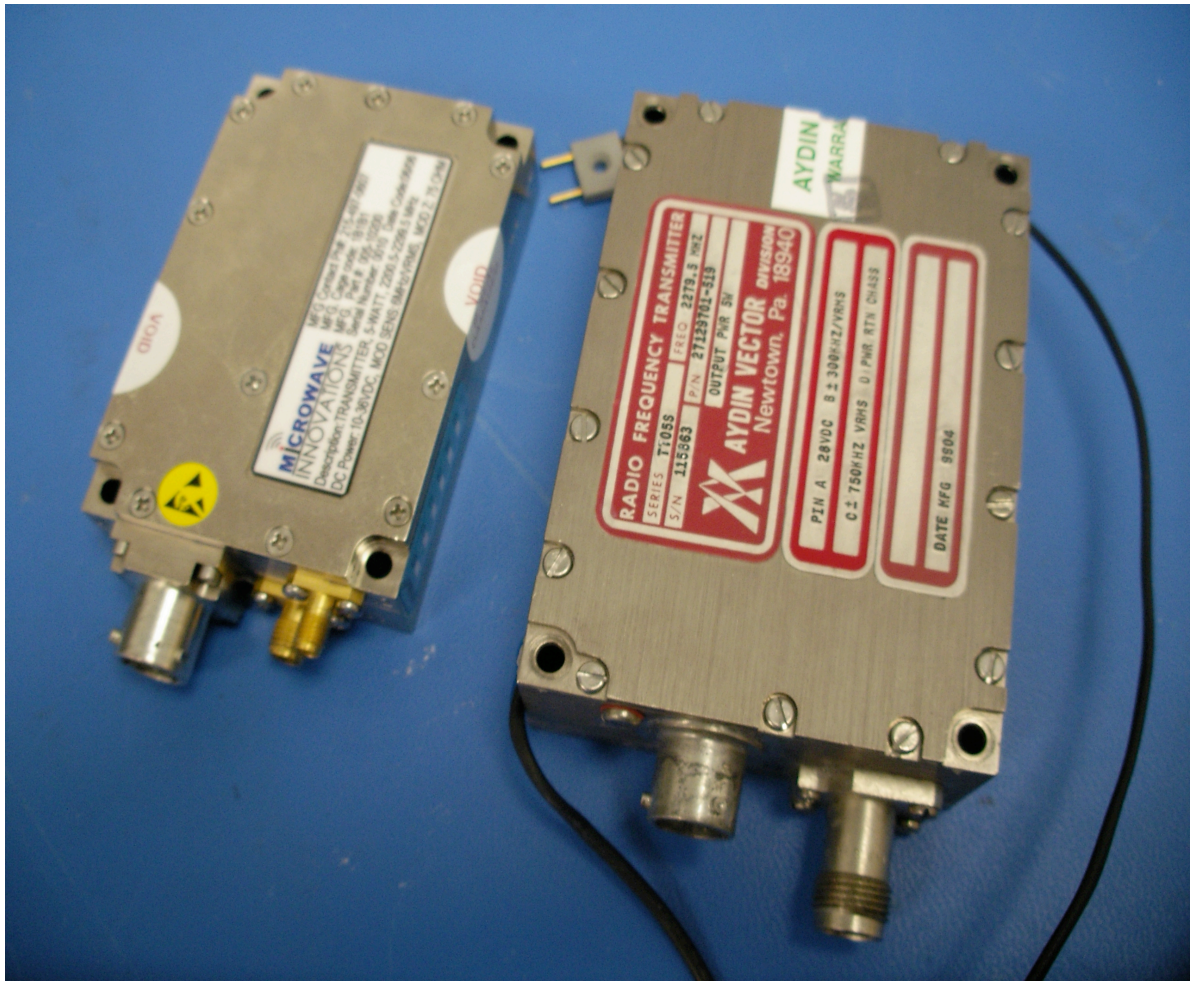
Program Benefit

- Reduce payload weight due to smaller battery and heat sinking mass requirements
- Frequency agility allows only having to purchase/stock one model per RF power rating

Status

- 5 each 2 Watt and 5 Watt received. Environmental qualification testing completed on both 2 & 5 Watt First Article
- Two 5 Watt units successfully flown on 40.020 Lessard
- 2 Watt successfully flown on 41.068 Seybold for TV Camera Data. This model is planned for use in the Mesquito payloads.

Wide Band, High Efficiency
5 Watt Transmitters



Wide Band, High Efficiency 2 Watt Transmitters

Mesquito PCM

Program Benefits

- System designed and built in-house allowing mechanical design to be custom tailored to Mesquito application
- Low cost by fabricating system in-house

Implementation

- Designing with a modular approach with stackable add-on data modules
- Presently targeting 16 analog inputs per module with 48 channel max and configurable serial digital or asynchronous data module with 2 inputs each

Breadboard Test Results

- Synchronous serial digital data rates up to 2 M BPS
- Asynchronous data input rates up to 230.4 K baud
- Analog data with 16 bit resolution

Status

- PC board layout for all boards has been completed
- All PC boards have been procured & received
- All PC board components hardware has been ordered

Mesquito Power Switching

Program Benefits

- Traditional mechanical relays are too large for use in the extremely space and weight limited Mesquito payload
- Mechanical relays may not survive 100-120 G's acceleration
- Two mechanical relays are ~$500, whereas two solid state switches are ~$25

Implementation

- Surface mount circuit technology
- Device selected are rated for 4.5Amps

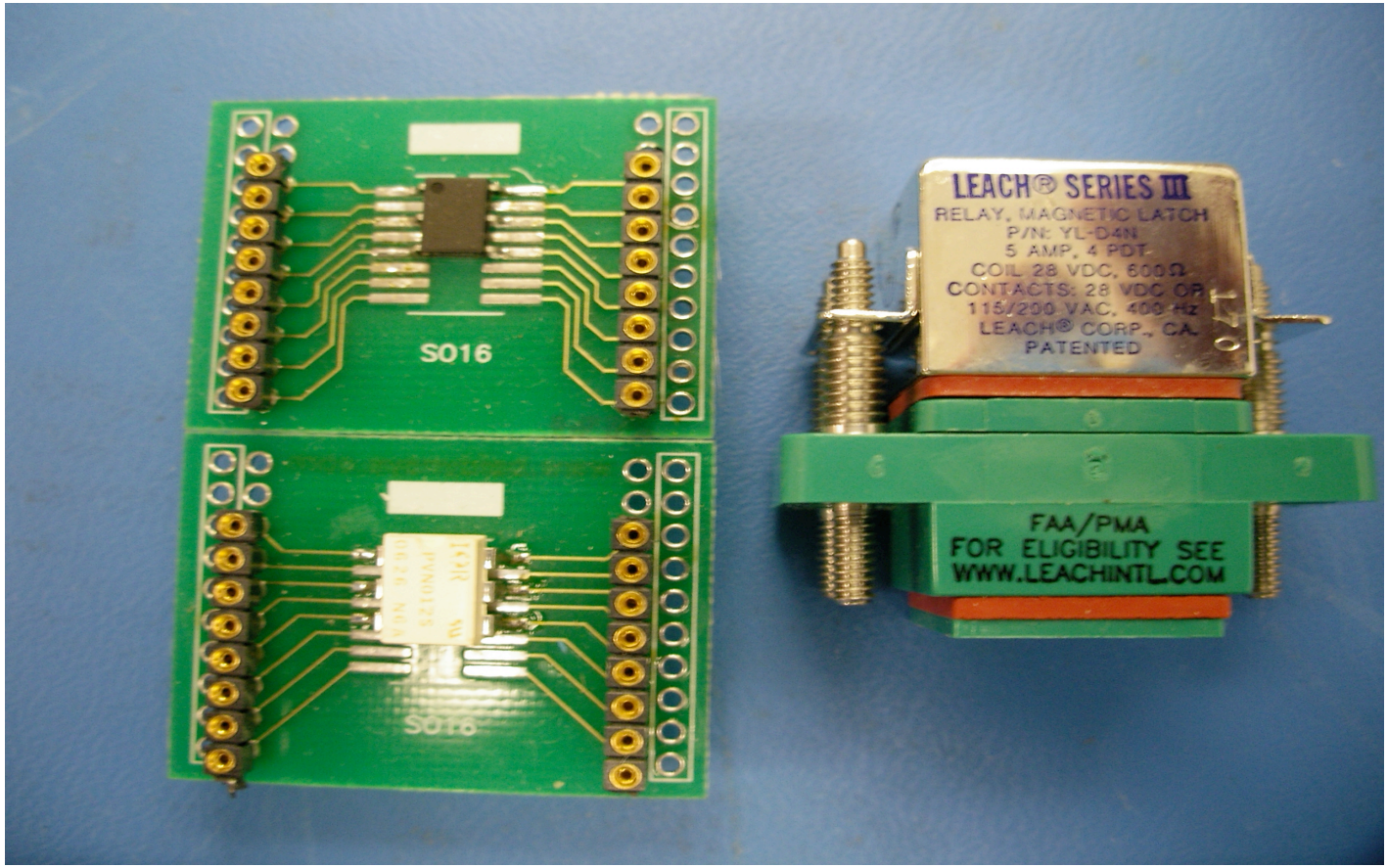
Breadboard Test Results

- Tested at 4 Amps continuous for 4 hours
- Tested 2 hours while switching on and off at 1 Hz while loading at 4 Amps

Status

- Schematic design of TM and Exp power switching and distribution completed
- Included housekeeping monitor circuitry in TM power switching board

Mesquito Power Switching



Mesquito Current Sensing

Program Benefits

- Traditional current sensors are too large for use in the extremely space and weight limited Mesquito payload

Implementation

- Surface mount circuit technology using high power low resistance (0.01 Ohm) voltage dropping resistor with Kelvin connections.
- Circuitry designed for monitoring 0 – 5 Amps

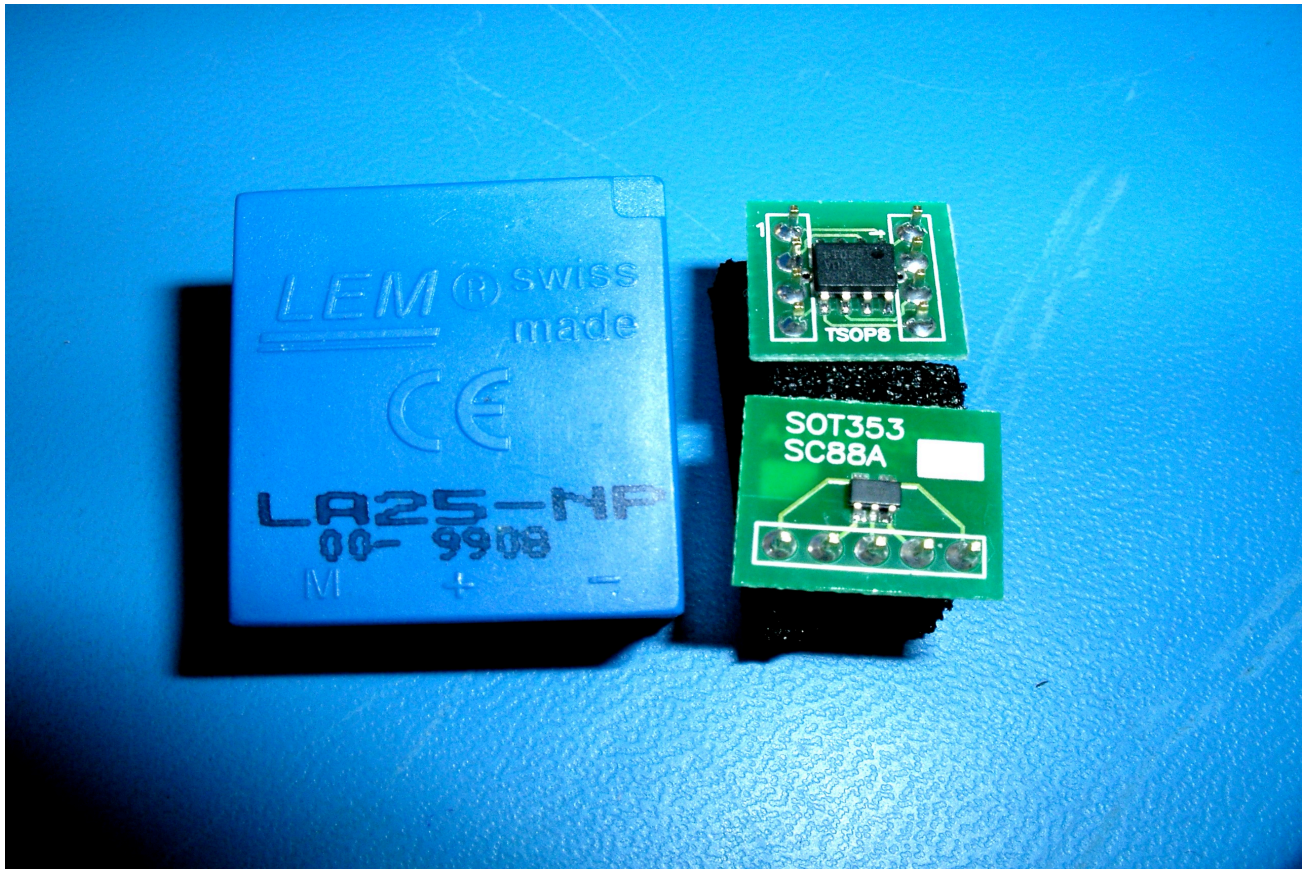
Breadboard Test Results

- Extremely linear over the 0 – 5 Amp range
- No low end sensitivity issues as noted with the present Hall effect sensors

Status

- Design incorporated on same PC board as the TM & Exp solid state power switching circuitry
- Ready to submit design to shop for board layout

Mesquito Current Sensing



Payload Power Control and Distribution

Program Benefits

- Eliminates payload wiring (power bus, ground bus, relays)
- Replaces a complete payload power system
- Can be tested prior to payload wiring

Flight Results

- Initial design successfully flown on 12.063 Hickman and 41.068 Seybold

Redesign

- Combined controller, power distribution and power switching on one board

Status

- All PC boards and component hardware have been procured & received
- Housing is currently being fabricated
- Planned to fly on 41.075 Smith

New Battery Technology

Issues

- Weight critical payloads need higher power density power systems
- NiCad batteries have environmental concerns

Implementation

- NSROC EE has investigated Nickel Metal Hydride and Lithium Ion battery technologies

NiMH Battery Status

- Flew 24 cell pack rated at 850 mAH 12.063 Hickman
- Flew 24 cell pack rated at 4.0 AH on 41.068 Seybold
- Ordered 1650 mAH, 3.0 AH, and 9.0 AH cells for stock

Lithium Ion Battery Status

- Purchased three evaluation batteries
- Plan to fly on 41.075 Smith

Remote Payload Control System +

Issues

- NASA and Navy required the RPCS to control Hazardous CDI systems
- Required to eliminate all copper connections between the blockhouse and launcher
- Required capability to log CDI system status, battery voltages and CAPOW voltages

Implementation

- NSROC designed and developed the software and hardware to meet the new requirements.
- Implemented a Fail Safe System

Status

- RPCS+ is capable of supporting 4 CDI systems
- Navy unit upgraded and has been used to support two ARAV missions
- One NASA unit has been upgraded and used to support one ARAV mission

New WFF93 PCM Modules

Serial FIFO Data Module

- The new Litton LN-250 and LN-251 IMU's have a 1.5 Mbaud asynchronous data output
- PSL developed a module to accommodate the 1.5 Mbaud data, called the Serial FIFO (First–In-First-Out) Data Module
- The new module has been incorporated and successfully integrated into 12.059 Costello and 36.220 McCandliss payloads

Low Level Analog Deck (LLAD)

- PSL developed a 24 Channel input, 16 bit resolution low level A/D module for thermocouples and other low voltage output sensors
- PSL will now manufacture a version of the module to accept high level (0-5 volt) inputs at 16 bit resolution
- The module has a two pole low pass anti-alias filter for each input
- Each filter can be tailored for appropriate data bandwidth
- This module will replace the current 4 channel remote A/D units which require addition of a serial digital deck and a power supply module.

Mechanical Engineering
&
Vehicle Engineering

Giovanni Rosanova

Mechanical Engineering

- Shocking news....
  - LaBelle Anomaly lessons learned (Pyro-shock destroyed rate sensors)
    - Need better understanding of shock in general.
      - This was also a finding from the vibration testing NAR.
      - NASA-STD-7003 is a good starting point.
      - Also need to collect data during T&E and flight.
      - AETD and NSROC are collaborating on a training course.
    - Need more careful consideration of where instruments are mounted in relation to shock sources
    - Need to consider isolation mounts when appropriate.
  - What the PI's can expect
    - More deployment testing for the sole purpose of monitoring shock
    - Being turned on and collecting data during deployment testing

Vehicle Engineering

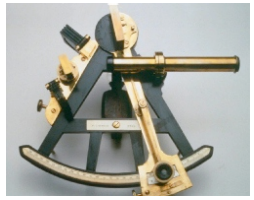
- Briefed WSMR Missile Flight Safety on Black Brant Mk1 vibration loads in the interest of maintaining approval of current TTS design.
  - Official response from MFS pending
  - First flight of BB Mk1 at WSMR is Chakrabarti in September
- Working with SRPO to develop risk mitigation plan for BBXII trajectory anomalies. Hypothesis is that absence of payload retract lug and two-week elevation time caused aft-most v-band to creep. Possibilities include:
  - Extended time bent test to check for joint creep
  - Stow launcher between launch attempts and “exercise” joints with belly band

  Unrelated to creep:
  - Re-torque aft v-bands after elevating
  - Measure Nihka run-out and parallelism

NSROC GNC

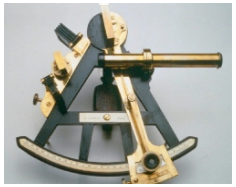
Ron Kiefer

NSROC GNC



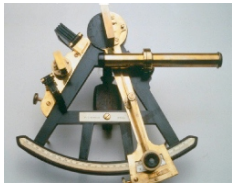
- ST-5000 Manufacturing (SRWG Comments)
- Celestial ACS
  - ST-5000 Focus
  - Linear Thrust Module (Precision Pointing)
  - Air Bearing Performance
  - Celestial Mission Schedule
- GPS Velocity Vector Input to NIACS
- Poker Flat Campaign, 2007
- HCI Performance
- New Technology
  - SPARCS Roll Gyro
  - Upgraded SPARCS LISS Electronics
  - Improved Command Uplink System
  - Inexpensive RTAS (Real-Time Attitude System)

SRWG Comments on ST5000 Star Tracker



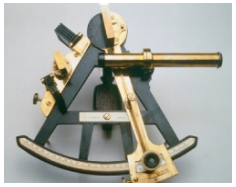
- NSROC GNC had stated that ST5000 star trackers would be built at UWISC
- Dr Nordsieck questioned this and the SRWG concurred that future ST5000 should be built at NSROC
- THIS IS ALL A MISUNDERSTANDING
  - We have no intention of asking UWISC to manufacture for production
  - ST5000 requires mechanical redesign & electrical improvements
    - Mandated by AIB – and it is a good idea
  - UW ST5000 engineers are eager to upgrade ST-5000
    - We are constantly learning and seeing possible improvements
  - Cannot proceed to ST5000 manufacture at WFF until redesign finished and ST-5000 is flight qualified
  - UW is building 2 more current design with NSROC parts
  - This will meet our requirements for several years
  - If we can sell the new design, we will build the new design.

ST-5000 Focus Issues



- ST-5000 has very short focal length (~F1)
  - Required for adequate photon counts with small (short) telescope
  - Extremely sensitive to small variations
- Focus is slightly different in air and vacuum
  - Temperature and vibration could possibly cause problems – haven't seen yet
  - ST-5000 is deliberately defocused to improve centroid accuracy
    (thus, there is not a requirement for perfect focus)
  - Differences in focus must be accounted for
  - UW has developed optical test set to focus for both air and vacuum
  - UW attempts to balance focus to be same in both air and vacuum – slightly defocused for each.
- Differential tracking algorithm has been improved
  - Drift causes noise and jitter as pixel boundaries are crossed
  - Better centroid algorithm and improvements to algorithm logic have been implemented.
  - When a star goes invalid it is no longer dropped from track list. We continue to look for it.
- We continue to learn and improve the ST5000 algorithms and its interaction with the Celestial ACS

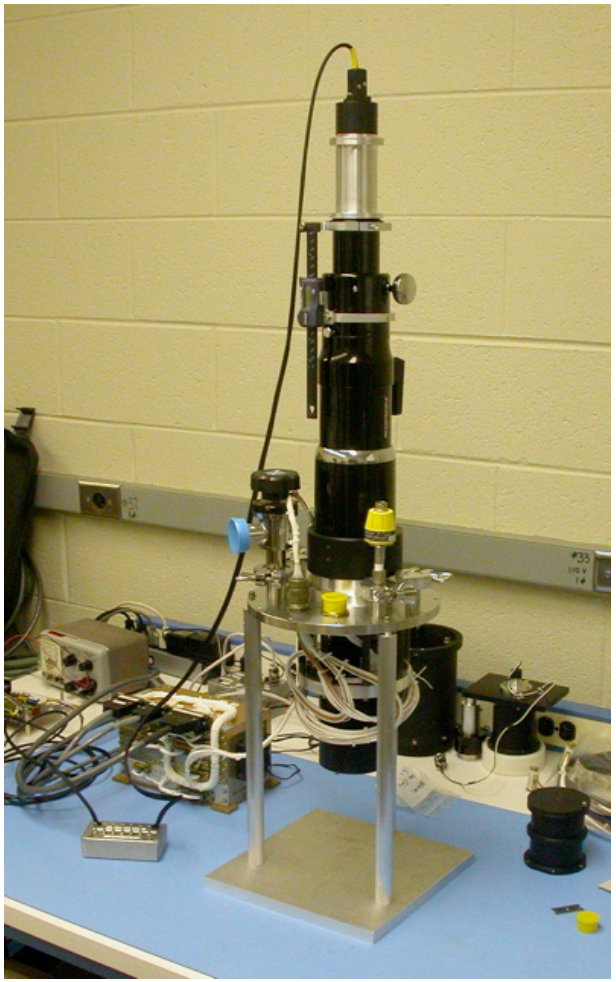
ST5000 Focus Test Set



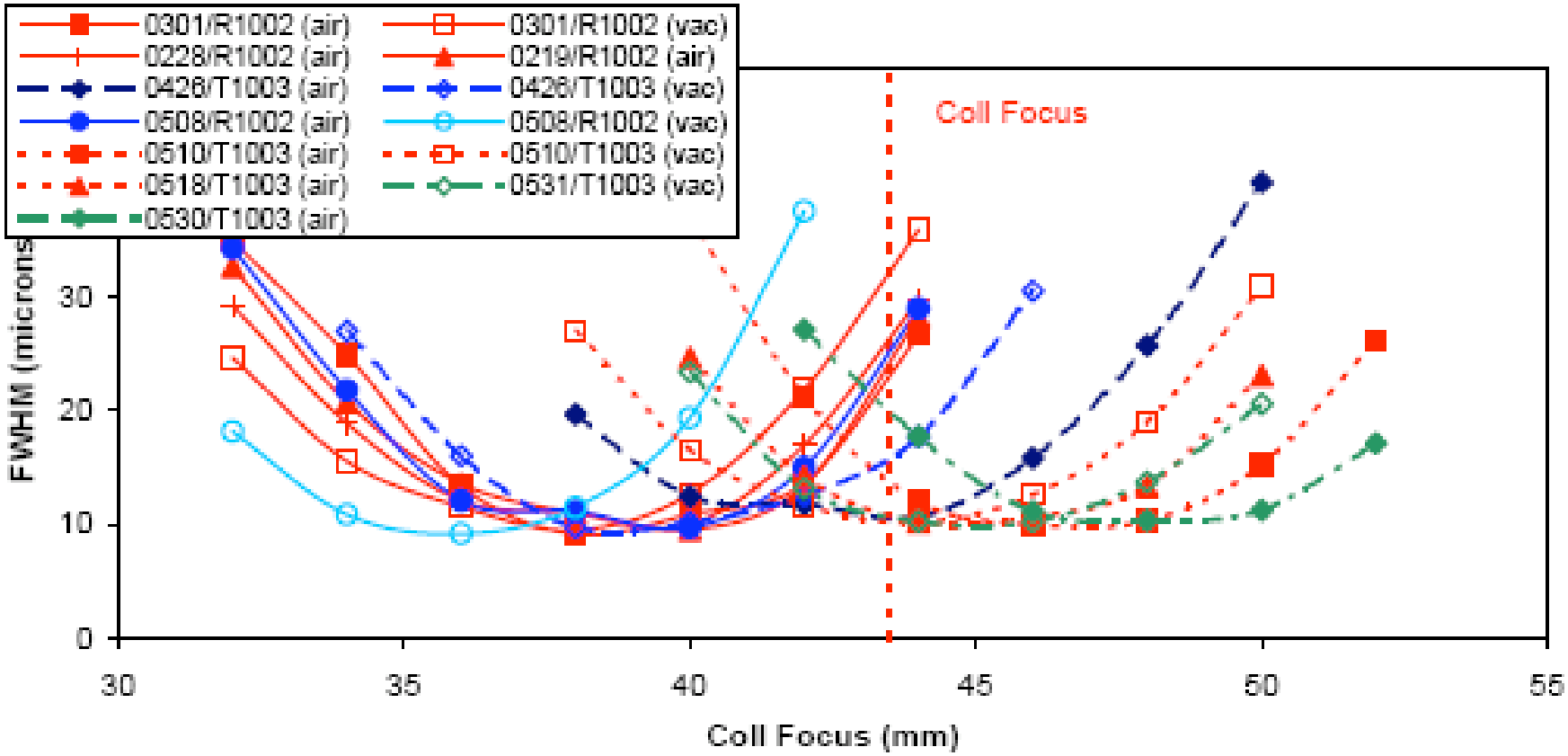
Focus Study:

Built a full aperture, adjustable focus collimator

- F/8, 480 mm telescope
- Digital vernier
- Reliable, reproducible focus with tracker head in air or vacuum
- Current-regulated LED light source with up to 8 selectable stars

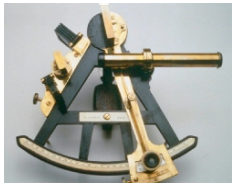


ST5000 Focus Test Data



Fine Linear Thrust Module LTM

formerly known as Tri-level pneumatics



- 4 AliCat Pressure Controllers
  - Differential flow produces a smooth, steady state free of solenoid actuation
  - Precision Ruby Orifices
- LN-251 IMU Fine
- 2 3 x 4 x 1 boxes
  - Voltage Regulators for Pressure Controllers
  - RS-232 to RS-422 Converter for Pressure Controllers
- 8.375” long x 17.26” skin section

LN-251 IMU

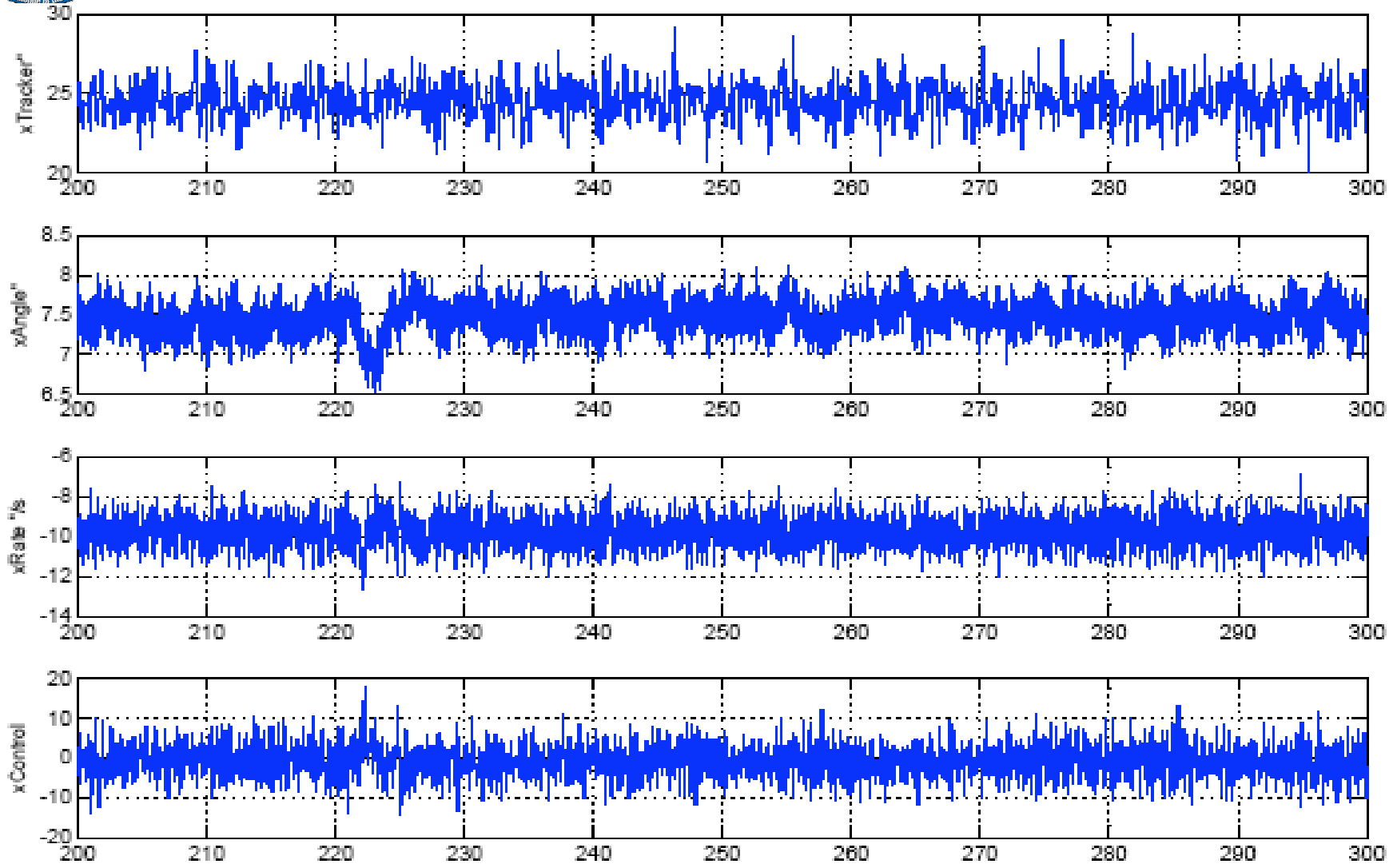
- 10.2 x 5.5 x 7.6 inches
- RS-422 Serial Interface @ 1.5 Mbaud
- 28 Volts
- 25 Watts
- 12 lbs

Pressure Controllers

- 0 – 150 psi
- 15 Volts DC
- RS-232 serial interface
- 38.4 kbaud (8-n-1)
- Controller parameters are configurable
- Ruggedized for NSROC
  - 9 pin mil-spec D connector
  - Removed the display board
  - Fully Potted (NSROC)
  - Serial message format expanded for more resolution
  - Tuned for fast response

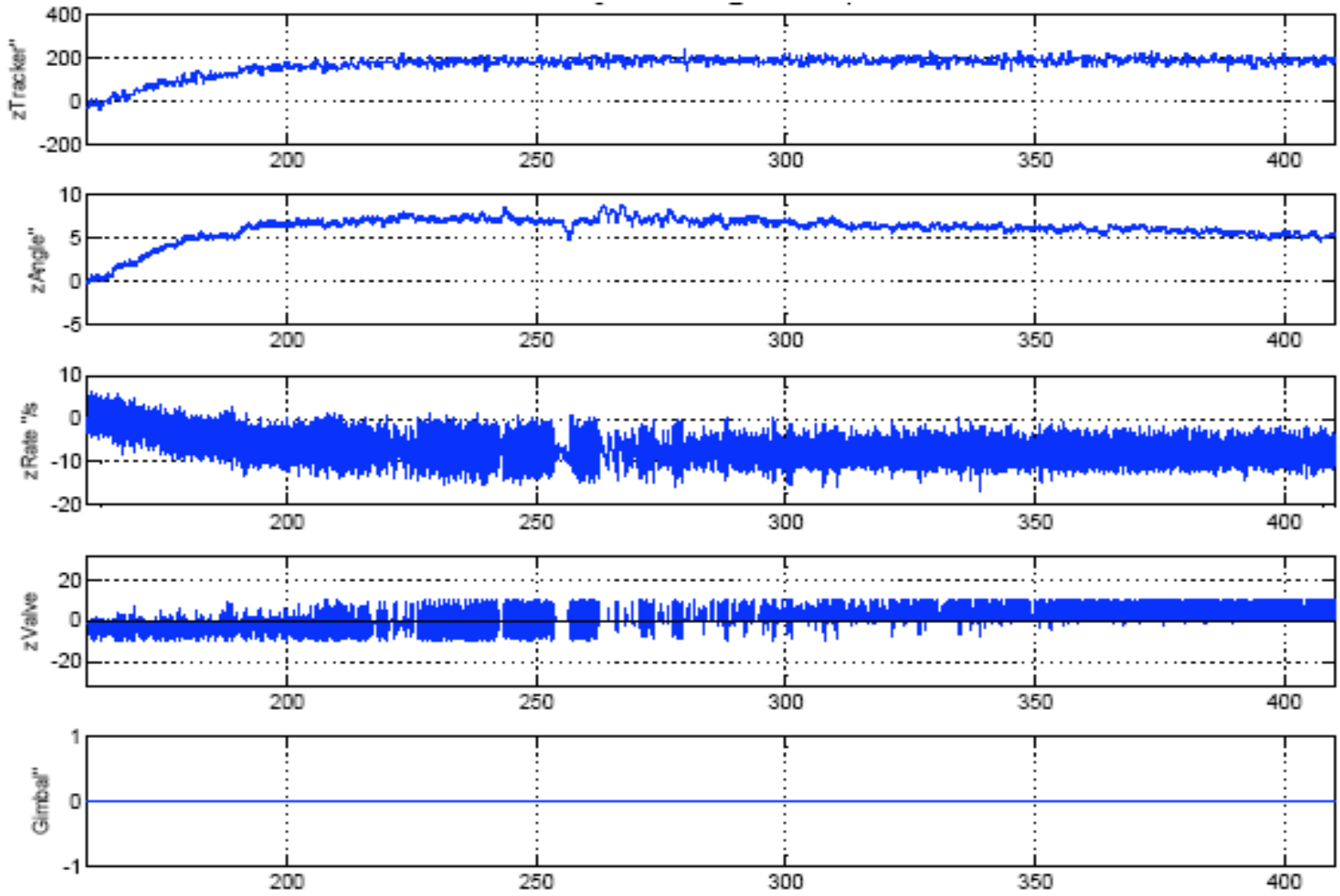
Demonstrated Performance

(ACS attitude)



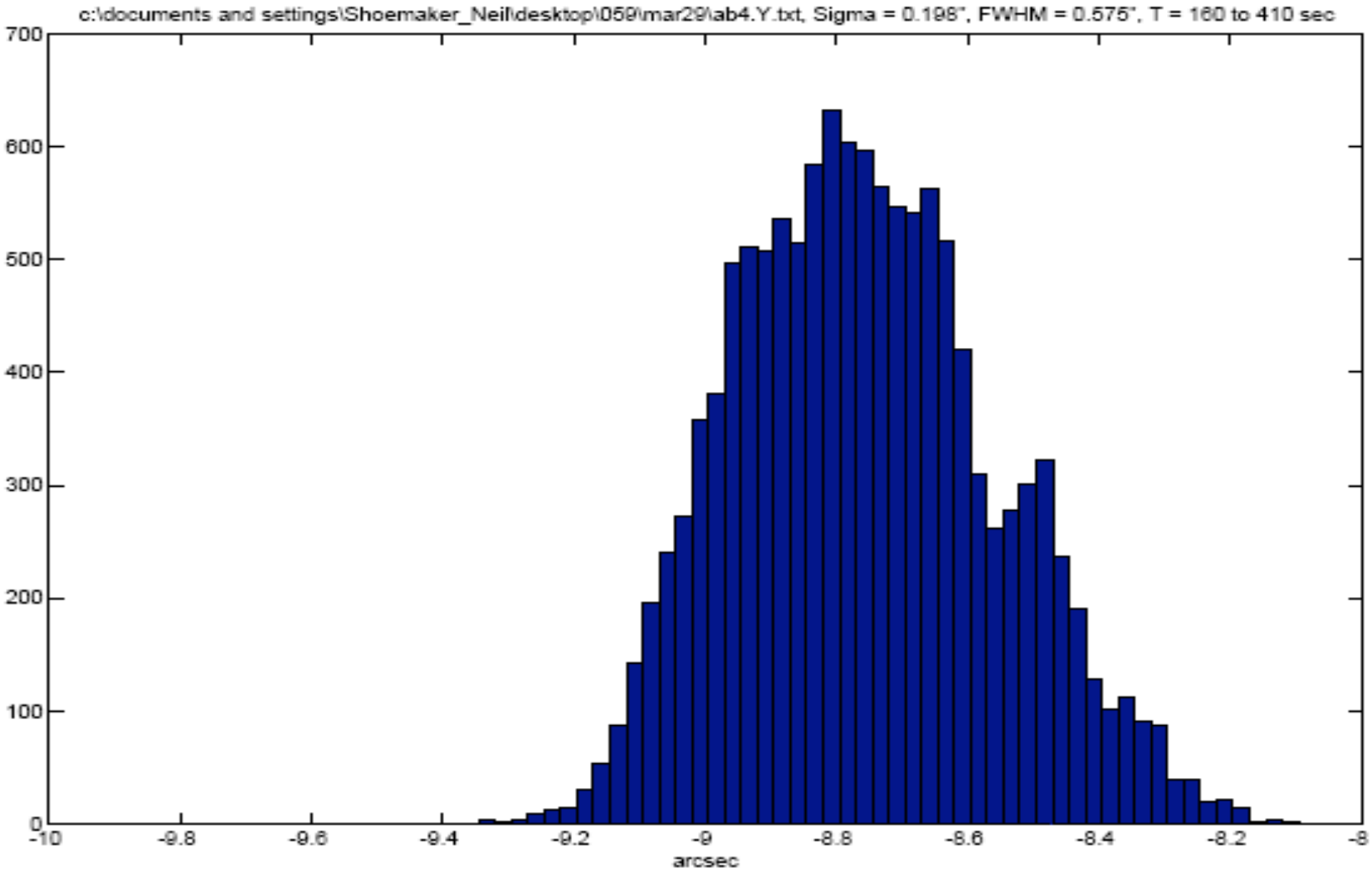
Airbearing Pointing Performance

Roll, 260 seconds



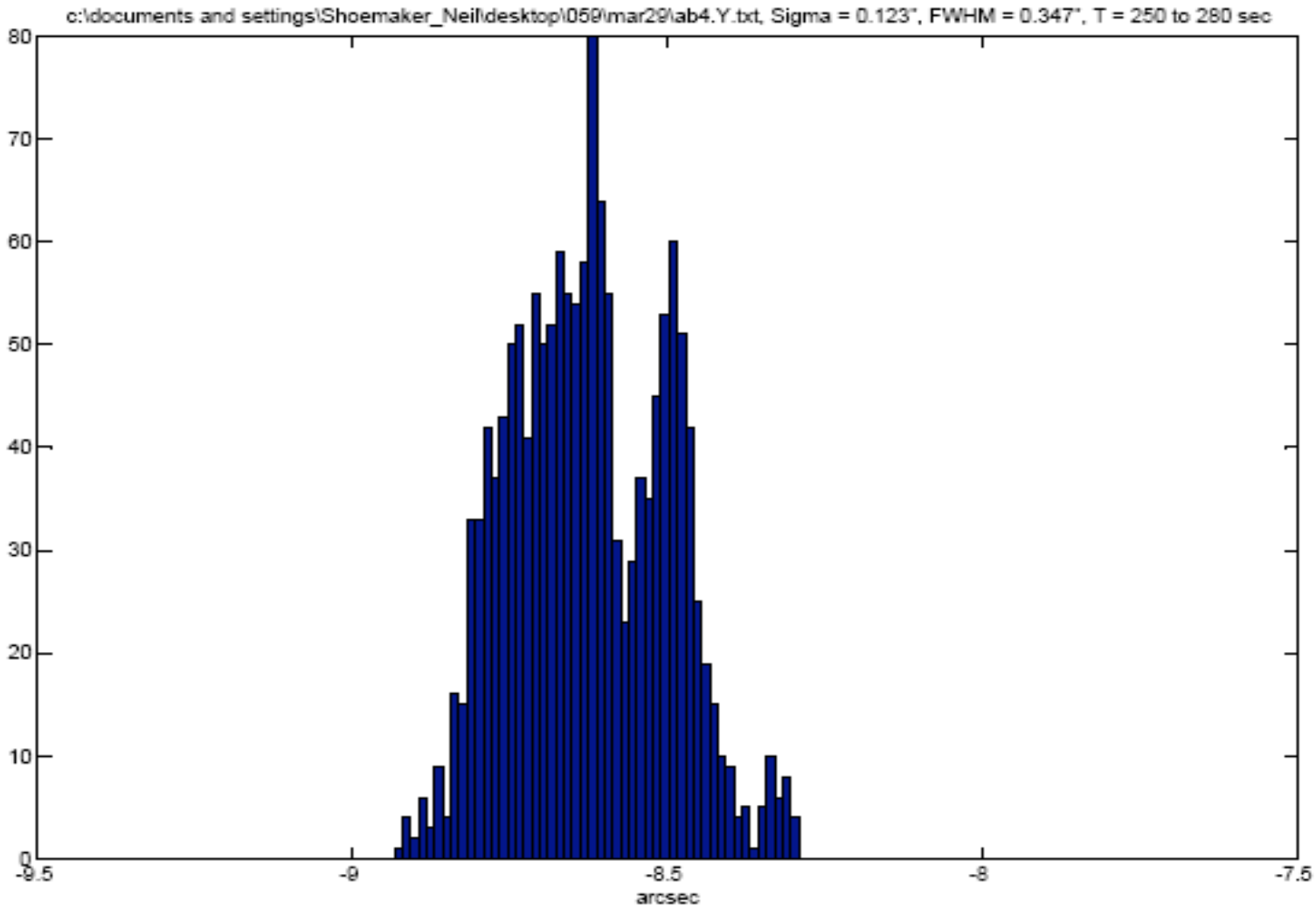
Airbearing Pointing Performance

Side to Side Histogram, 260 seconds

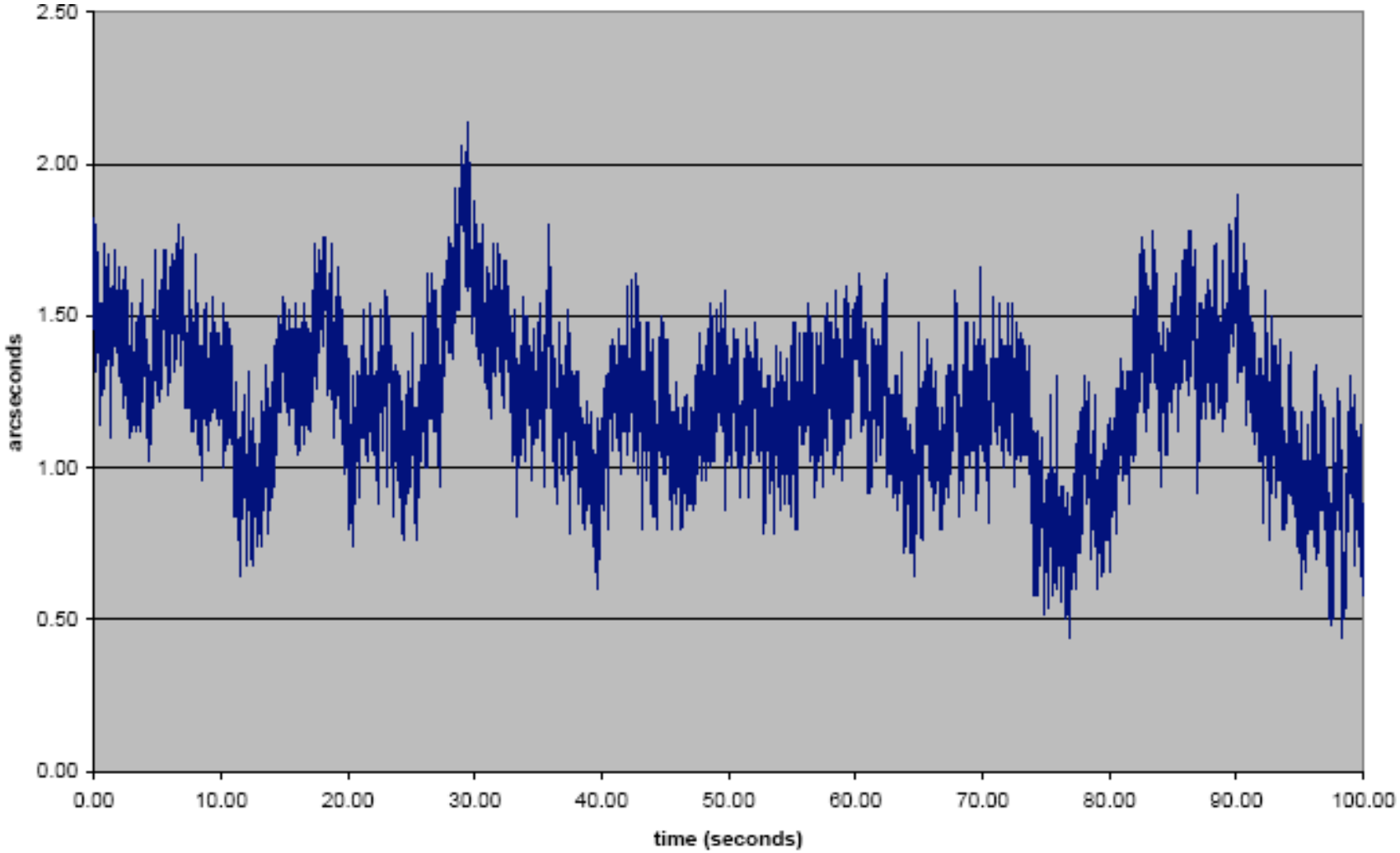


Airbearing Pointing Performance

Side to Side Histogram, 30 seconds

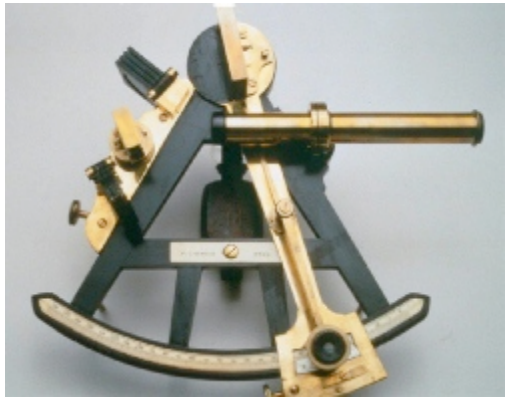


Demonstrated Pointing
(analog LACkey)



Scheduled Celestial Missions

- 12.059 Costello 21 Jun 2007 (test flight)
  - ST-5000 focus problem
  - Pressure Controller fine pitch-yaw control for Chakrabarti
  - LN-251 fine rate sensor
- 36.220 McCandliss 14 Jul 2007
  - Target position within +/- 5 arc-min
  - Command Uplink to 10 arc-sec Slit
- 36.225 Chakrabarti 4 Sep 2007
  - Must acquire within 1 arc-sec
  - Very precise control based on science provided “perfect” error signal
  - Cooled shutter door is presenting challenges
- 36.207 Cruddace TBD (AeroJet OR Celestial)
  - Less than 1 arc-sec/sec jitter
  - Less than 0.2 arc-min/min drift
  - +/- 2 arc min target
- 36.226 Bock May 2008
  - 3 arc-sec max error in 20 seconds
  - Side looking ST-5000
- 36.235 Harris Jun 2008
  - 20-30 arc-sec



GPS Velocity Vector
Input to NIACS

- Seybold 41.068 WSMR Apr 2006 (successful test flight)
- Craven 35.037 Poker Flat Feb 2007 (input to experiment)
- Robertson 41.069/70 Andoya Aug 2007 (also test digital mag)
- Earle 36.218 Wallops Sep 2007 (year delay for science)

Poker Flat Campaign 2007

- Larsen – Success ☺
  - 2 NMACS with TM Gyros
  - Similar to Joule
  - Also 2 chemical rockets
- Lessard – Success ☺
  - NIACS
  - Complex sub-payloads with Horizon Crossing Indicators (HCI)
  - Roll valve partially open – roll rate too low – imager blurred
- Craven – Success ☺
  - NIACS & Digital Magnetometer
  - Trajectory modification similar to Conde
  - Velocity vector input to experiment
  - Also three instrumented chemical rockets with HCI
- LaBelle – Failure ☹
  - NMACS rate sensors failed at separation – due to pyrotechnic shock
  - Rate sensors mounted too close to pyros
  - Redesign will require shock isolation and known orientation of the gyro triad

Horizon Crossing Indicator (HCI) in Poker Flat Campaign 2007

- Lessard –
  - NIACS
  - 3 Horizon Crossing Indicators (HCI) on sub-payloads (2 FADS, Cowboy)
  - Good data obtained – pre-separation comparison with GLN-MAC
  - Noise obliterated signal when experiment high voltage turned on.
- LaBelle –
  - NMACS & TM Gyro
  - HCI for comparison with TM Gyro (GLN-MAC)
  - HCI not a requirement
  - Even with HCI anomaly, useful data was obtained
- Craven –
  - NIACS & Digital Magnetometer – no HCI
  - Also three instrumented chemical rockets with HCI & Magnetometer
  - Good data obtained

HCI Performance

- 7 HCI flown successfully
  - All HCI analog output was nominal with no loss of data and it successfully fulfilled the requirements
  - Actually all flights were after the specific period of performance (ended 31 Jan 2007)
  - Data reduction proceeding – is labor intensive – preliminary results indicate that 3 deg accuracy requirement was met.
  - Calibration of earth limb may improve accuracy
  - Digital pulse trigger design inconsistency .
    - NSROC time-event module triggers on trailing edge of pulse.
    - Space to earth pulse is wider than earth to space pulse.
    - Does not affect quality of data for post-flight data analysis
    - Needs to be corrected for future real-time applications

New Technology at WSMR

- SPARCS Ring Laser Gyro (RLG) GG1320
  - Successfully tested on the air-bearing
  - Successful piggyback on Judge
  - Order of magnitude better performance than current RIG
    (0.04 deg/hour vs. 0.5 deg/hour drift spec).
  - Replacing the RIG with the RLG will reduce weight and length of solar payloads.

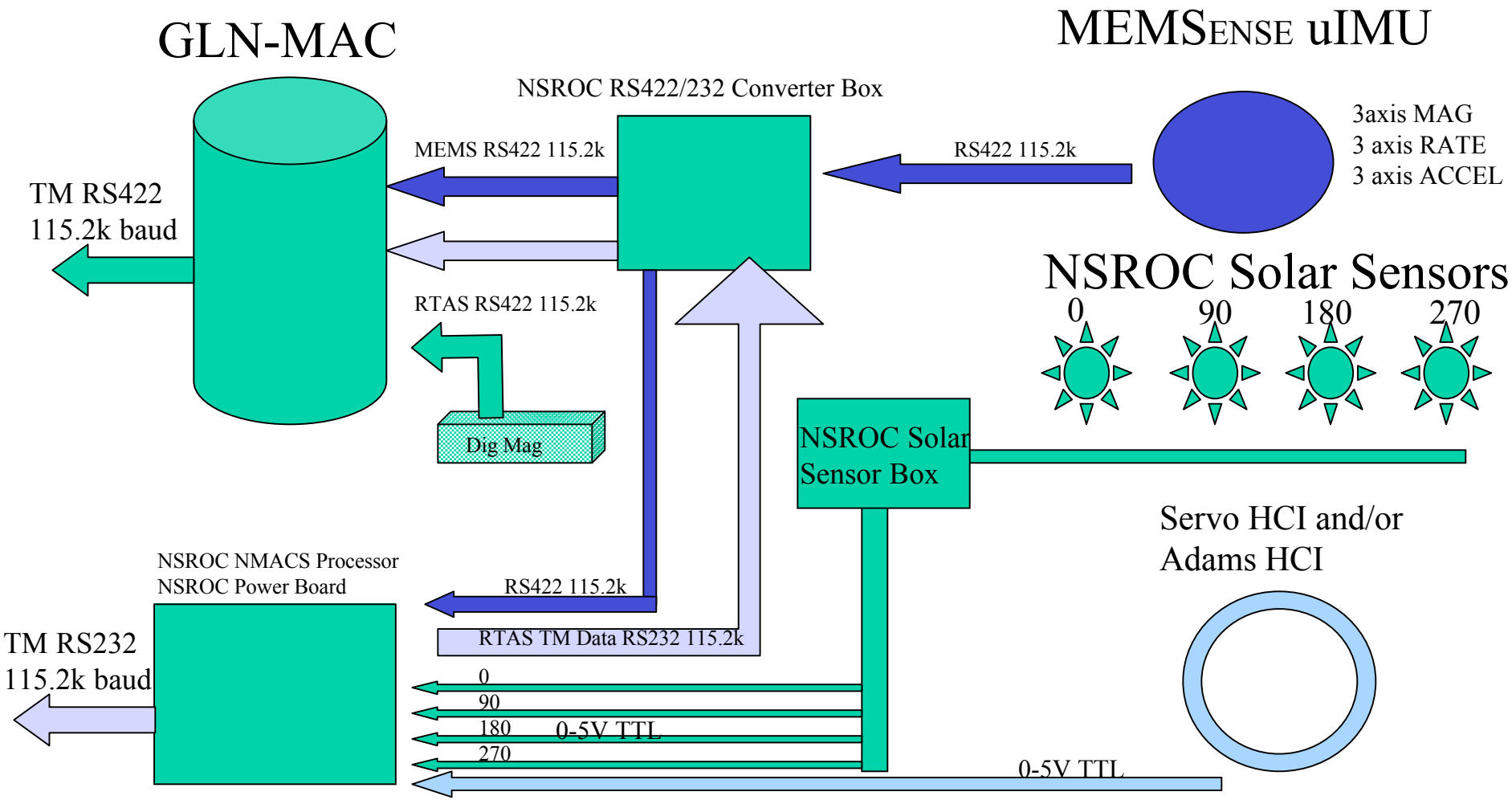
- Working on upgrades to the SPARCS LISS sun sensor electronics.
  - A new Printed Circuit Board was designed and tested with excellent results in the LISS noise and gain tests.
  - New design includes double gain capability for "super-fine" mode control mode.

- Improved Command Uplink System (CUS) is under development at WSMR
  - Conceptual design review held
  - SRPO approved task order
  - The present CUS system is aging and has had several problems
  - New CUS has improved GUI with touch screens and better real-time video display.

New Technology - RTAS

- **Real-Time Attitude System**
  - Joint WSMR – WFF efforts
  - Use inexpensive sensors (rate gyros, magnetometer, sun sensors, HCI)
  - WSMR researching and evaluating software tools and upgraded NMACS processor to support the RTAS (and NMACS also)
  - WSMR - Completed PCB layout design for Analog Device (ADI) small, low cost gyro chip.
  - WFF – Procuring uIMU (micro IMU from MEMsense)
  - WFF – Prototype System using GLN-MAC
    - Surrogate computer processor
    - Also run NIACS solution to compare
    - Flight Opportunity on Sub-Tec (Smith 41.075)
    - Will fly what is ready
  - Kalman filter to combine measurements
  - Is cheap in material but labor intensive
  - John Ozanne's view – just get a GLN-MAC

Prototype RTAS Block Diagram



Conclusions

- NSROC is committed to continuing the SRPO mission and program successes. 2007 has been a good year for Sounding Rockets.

- NSROC's Primary Goal is unchanged:
  - to satisfy the Code S PI mission requirements.

- NSROC is committed in expanding the technical innovations while
  - Meeting the requirements of the PIs
  - Maintaining a cost effective environment
  - Making effective use of the in-house talent, experience and hardware.

- NSROC's early receipt of the SRWG findings is important for future growth planning.
  - Thank you to the SRWG for providing these important findings